Mission Services Technology Group

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Agenda

- **Group Purpose / Charter**

- **Projects**
  - **Constellation Visualization System (CVS)**
  - **Visual Observation Layout Tool (VOLT)**
  - **Goal Oriented Commanding (GOC)**
  - **Advanced Spacecraft Trending Analysis Toolkit (ASTAT)**
  - **Applied Agent Research**
    - **Multi-Agent Systems (MAS)**

- **Discussion / Questions**

MST Group Purpose / Charter

- To identify, develop and demonstrate the key technologies that will significantly facilitate the reduction of mission operations costs and risk
  - Develop and demonstrate the necessary tools
  - Apply to current and future mission models
- Work with existing missions (especially flight operations personnel) to:
  - Analyze where the needs are
  - Identify the types of technologies that address the needs
  - Develop and deploy prototypes to analyze success of technology
- Work with future missions to develop understanding of the future challenges
  - Example: constellation management)

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MST Group Domains

Planning and scheduling on-board operations

- User (scientist) collaboration
- High-level (goal-oriented) commanding
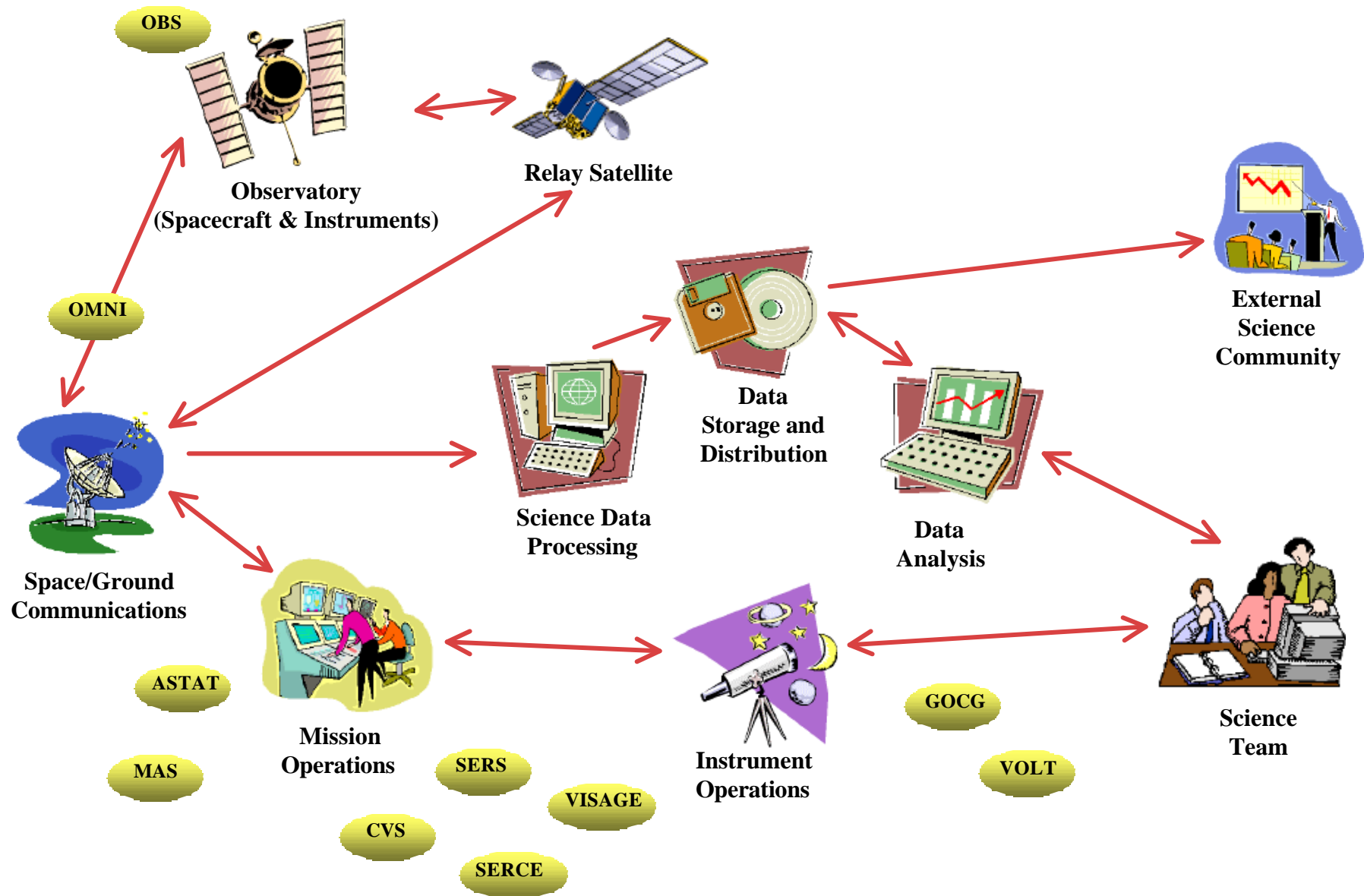- Agent technologies

Real-time monitoring of data

- Data visualization
- Expert systems
- Remote user paging
- Remote user access

Engineering analysis

- Advanced trending and analysis
- Remote, easy access to data
- Expert systems
- User collaboration

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Mission Services Technology

Constellation Visualization System (CVS)

CVS - Project Overview

- **Goal:**
    - **Research, apply, and infuse emerging visualization technologies to facilitate the cost-effective monitoring of multiple missions (e.g., constellations)**
- **Attempts to respond to the challenge of how to manage large constellations (perhaps 100) with minimal increases in staffing**
    - **New visualization techniques**
    - **Multispectral visualization, manipulation, and analysis**
    - **Advanced data modeling**
    - **Zoomable Interfaces**
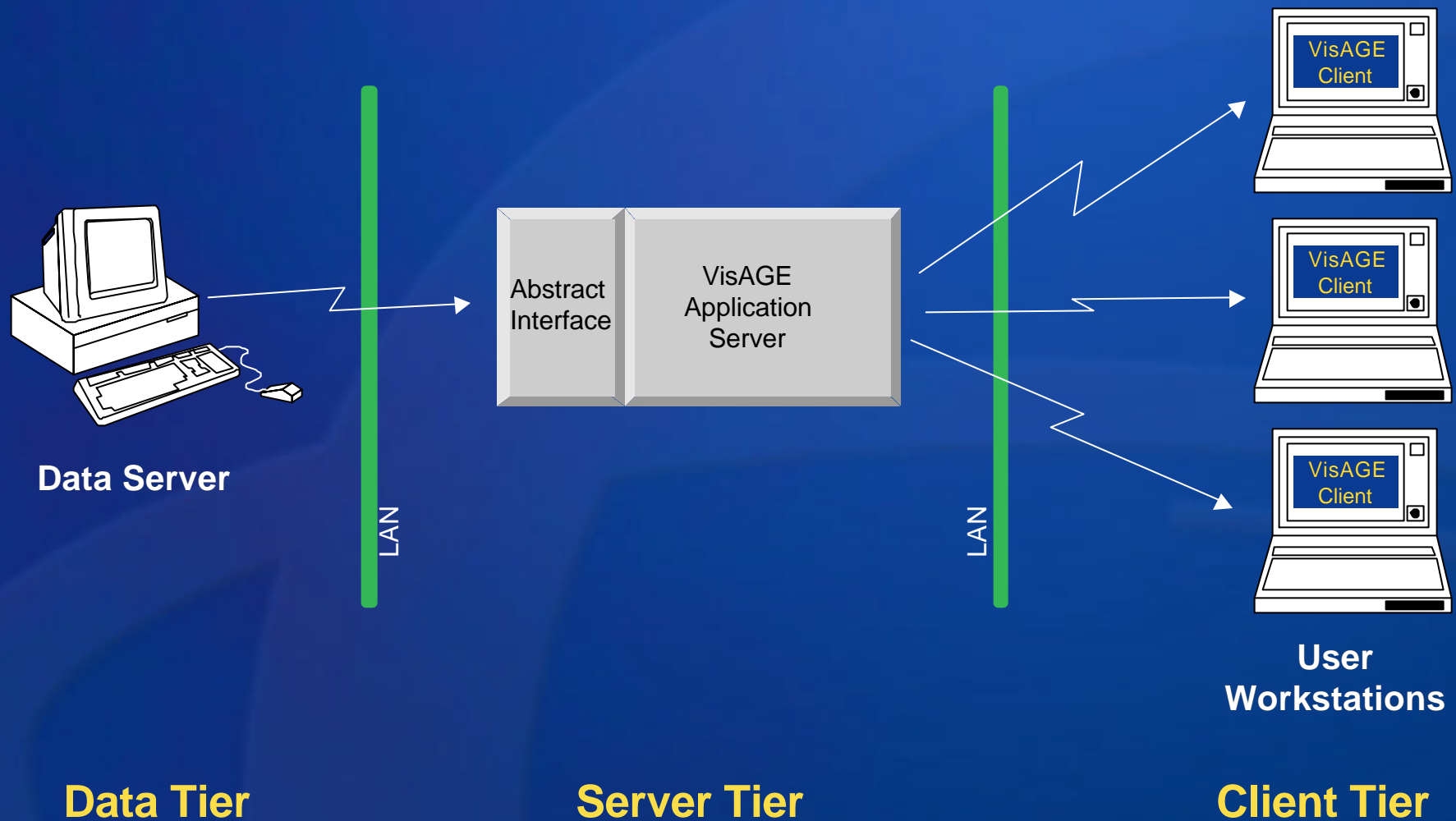   - **Provide an overview of all system data.**
        - **Enable user to filter and zoom to details**
    - **These combine to enhance operator's awareness of health and safety concerns**

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CVS - Project Overview

- **Based on VisAGE, a Java-based, platform-independent, extensible toolkit for data visualization**
  - A data distribution/visualization toolkit
  - Server easily adapts to any data source
  - Client plug-in architecture for managing/viewing data
  - Java RMI for distributing data to applications or applets.
  - Secure Socket Layer (SSL) ensures secure data transmission

CVS - Architecture

Data Server

LAN

Abstract
Interface

VisAGE
Application
Server

LAN

VisAGE
Client

VisAGE
Client

VisAGE
Client

**User
Workstations**

Data Tier

Server Tier

Client Tier

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CVS - Technologies

- ? **100% Java**
  - ? **Java Remote Method Invocation (RMI)**
  - ? **Java 2D**
  - ? **Java 3D**
  - ? **Java Help**
- ? **Industry standard protocols**
  - ? **Extensible Markup Language (XML)**
  - ? **Secure Socket Layer (SSL)**

CVS - Research Opportunities

- **New innovative approaches to monitoring observatory status, particularly for multi-satellite configurations (e.g., constellations)**

- **Standard methods for communicating with heterogeneous set of applications**
  - **Would allow data to be retrieved from different missions (with different applications) in common way**

- **Standard methods for representing data (telemetry)**
  - **XML?**

Constellation Screen Shots

Bullseye Visualization

- Line length lines indicates current satellite "health index" (0% to 100%).

- Lines pierce Green, yellow, or red thresholds as the health index changes.

- Apply filters: Top X, visible S/C only
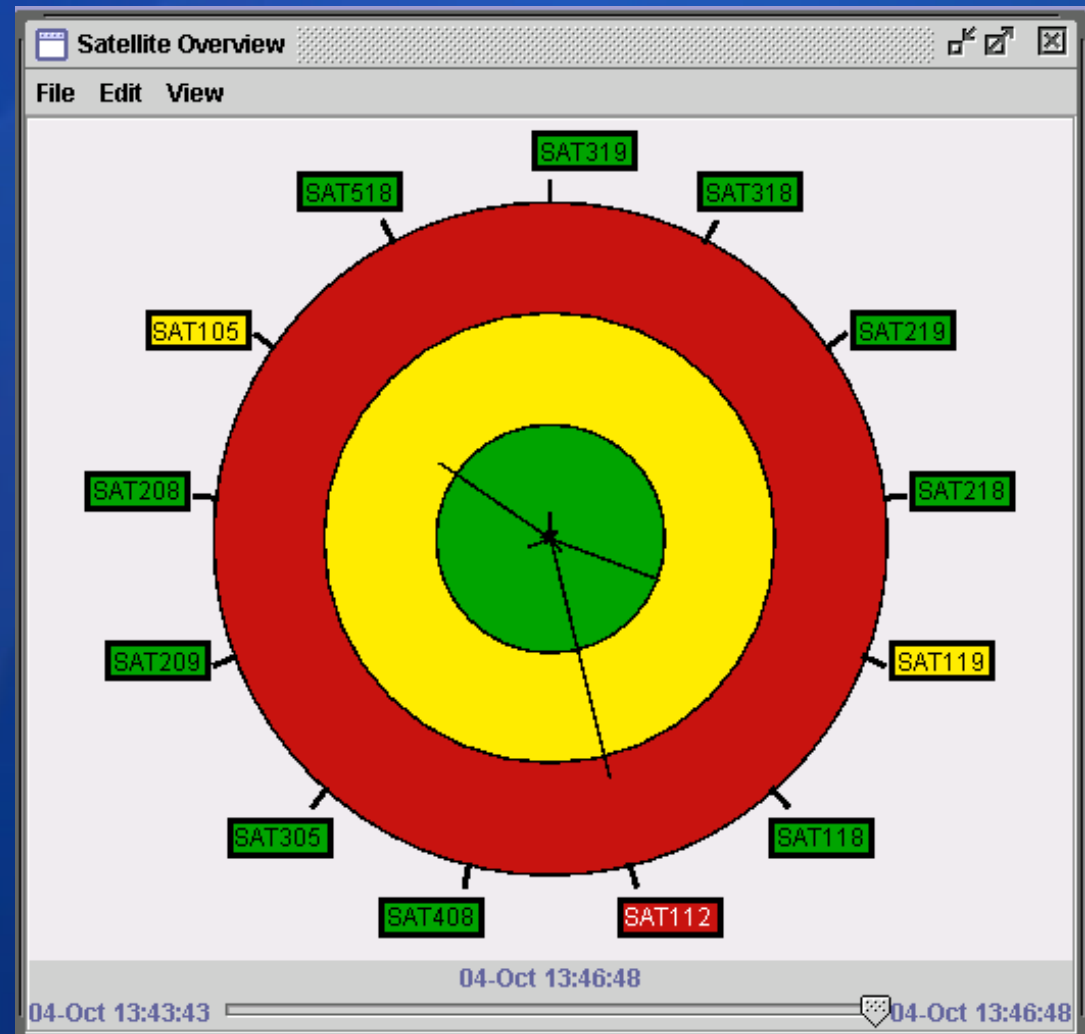
Constellation Abacus Visualization

- Triangle in each row indicates current health (0% to 100%)

- Triangle direction (arrow) indicates direction of last movement of triangle.

- Bold segment indicates the range of health during the "recent past".
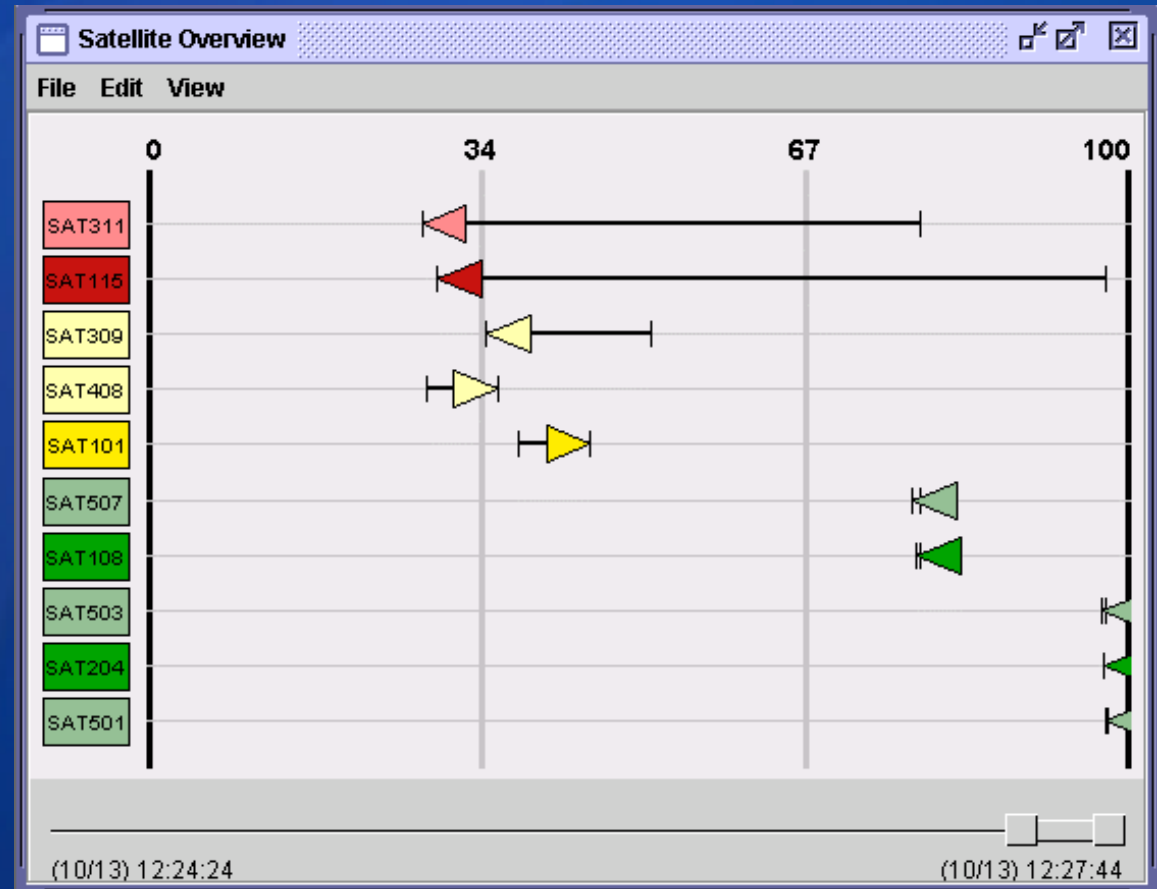
Mnemonic Abacus Visualization

- ✍ **Triangle in each row indicates current telemetry value**

- ✍ **Triangle direction (arrow) indicates direction of last movement of triangle**

- ✍ **Bold segment indicates the data range during the "recent past"**
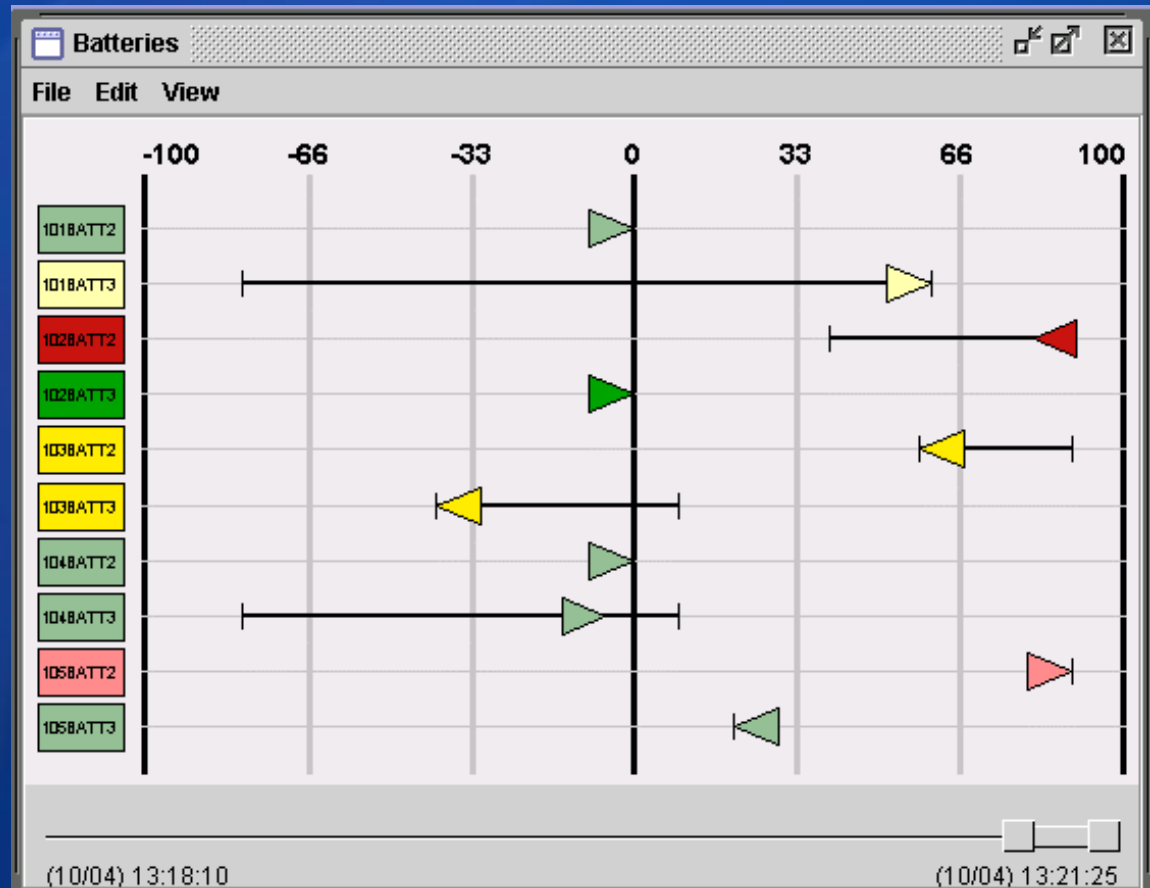
Grid Visualization

? **Shows health status for selected satellites and subsystems in one color-coded table**

? **Clicking on a satellite label, subsystem label, or square displays the current value**

? **Supports multiple sorting and filtering capabilities**

? **Double-click satellite or subsystem label to drill-down to details**
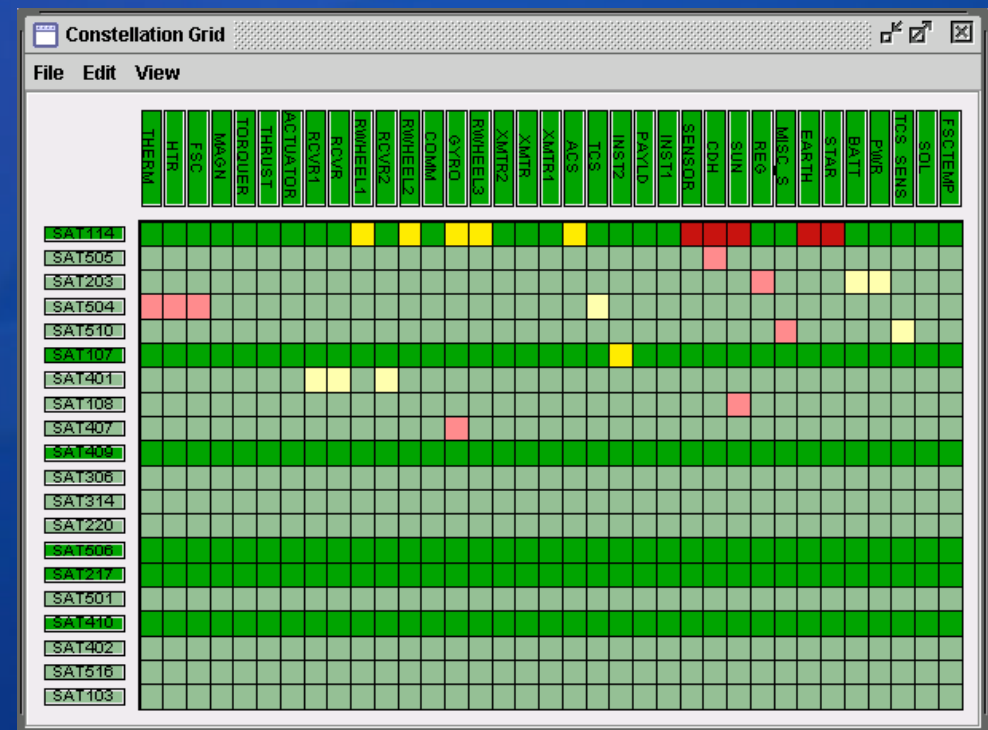
Browser Visualization

- Browses the entire constellation mnemonic hierarchy with an intuitive tree representation

- Presents Satellite and Subsystem View

- Indicates red-yellow-green health status

- Indicates satellite visibility (intense colors versus pastels)

- Can drill down all the way to mnemonic telemetry values
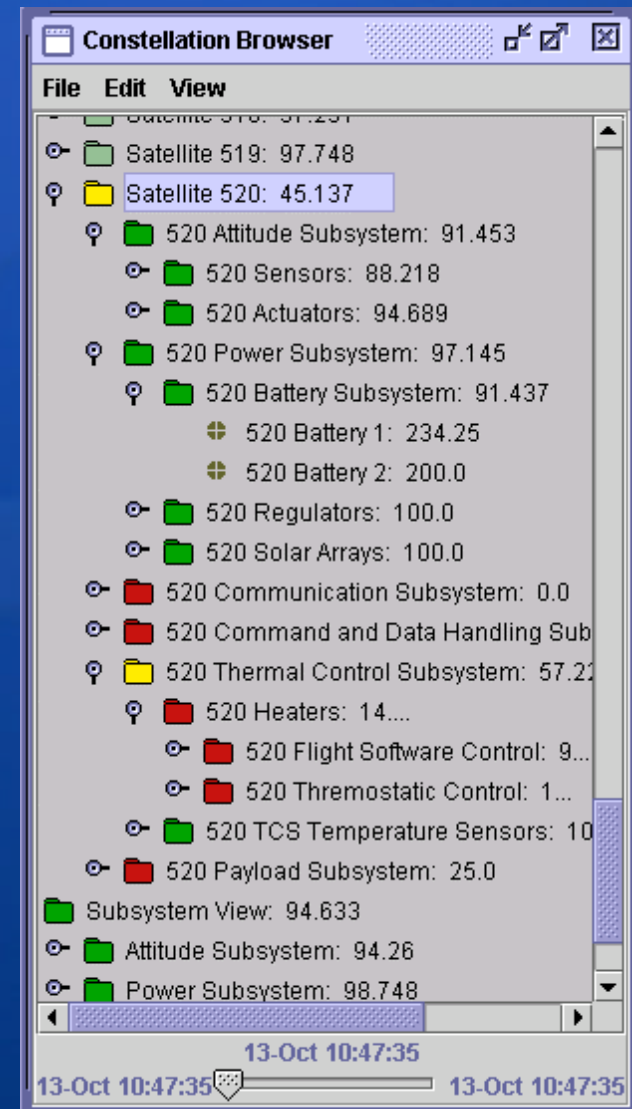
Data Carousel Visualization

- Provides executive summary for 100 spacecraft

- Indicates satellite visibility (intense colors versus pastels)

- Current value within threshold displayed along the binding

- User can rotate the carousel to desired position
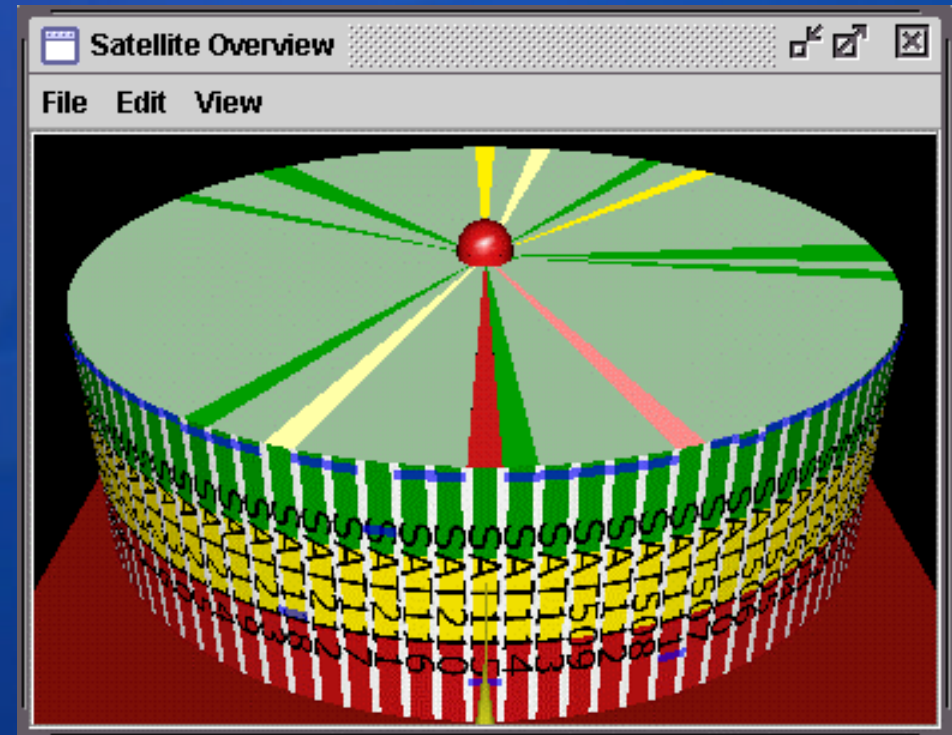
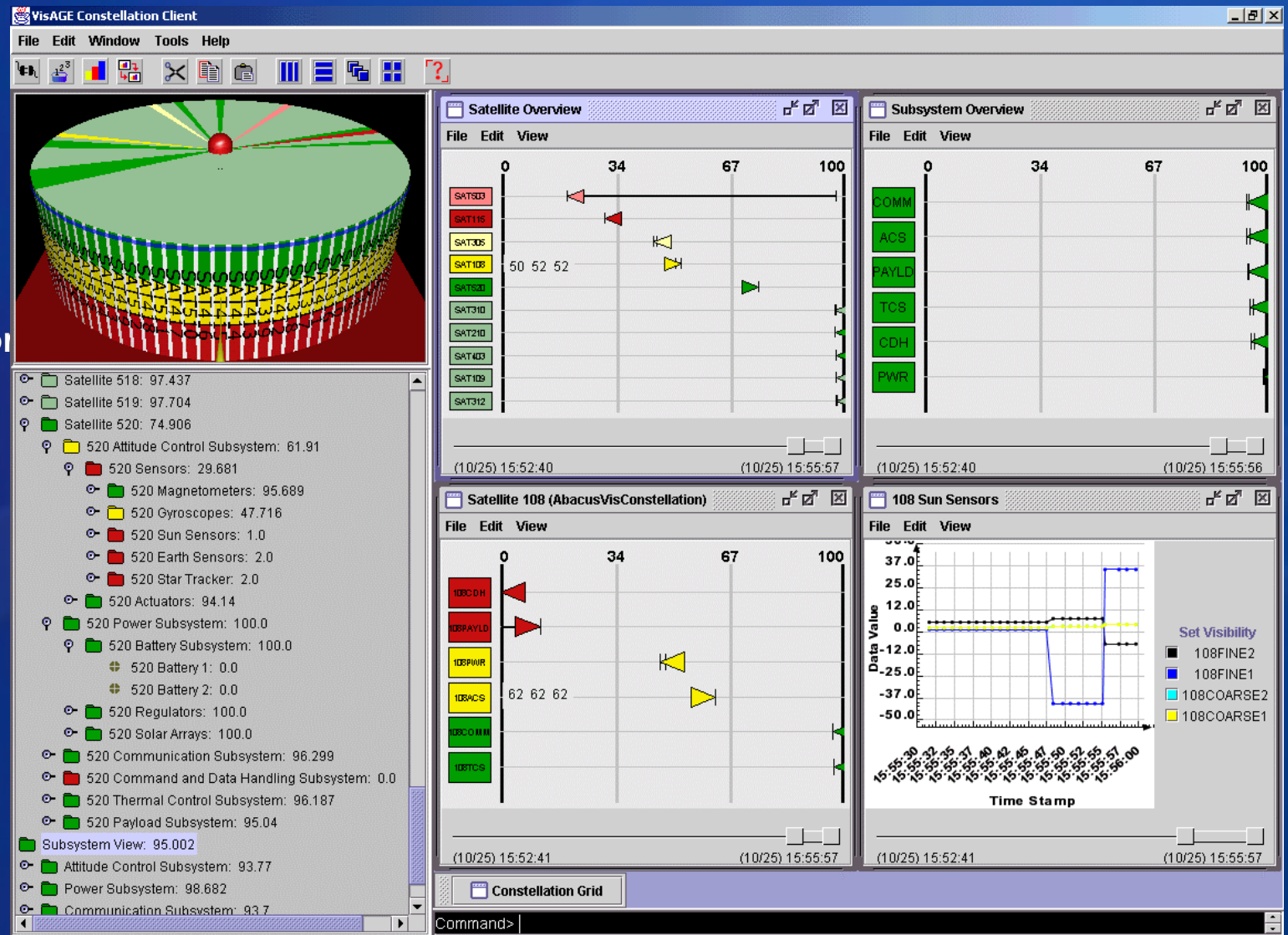# Carousel Animation

? **From overview to detailed strip chart…**
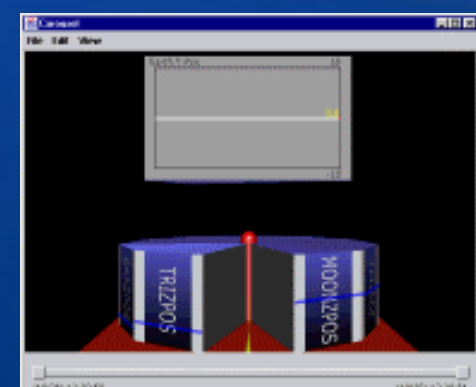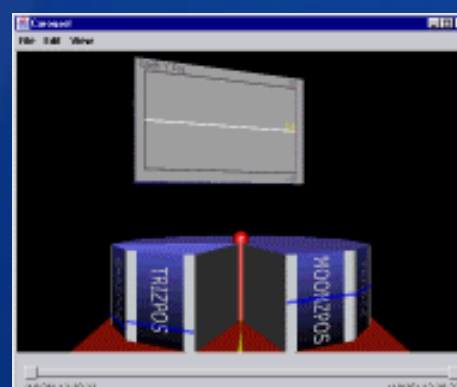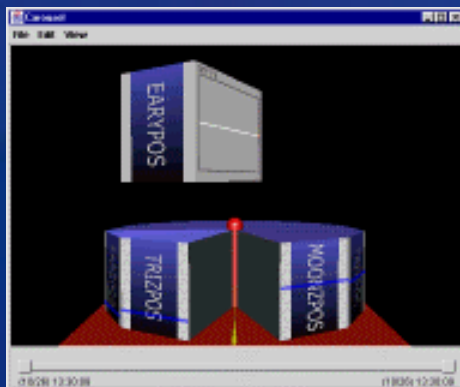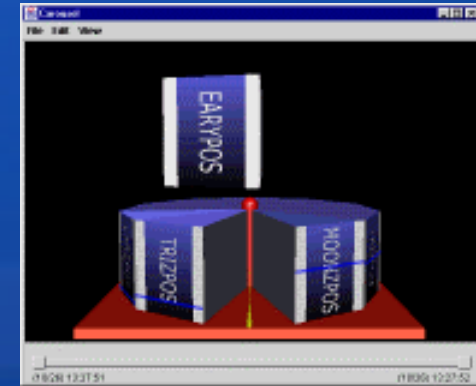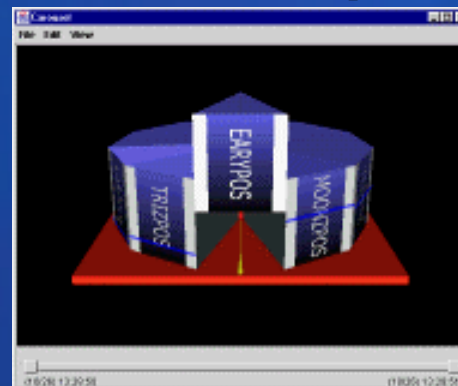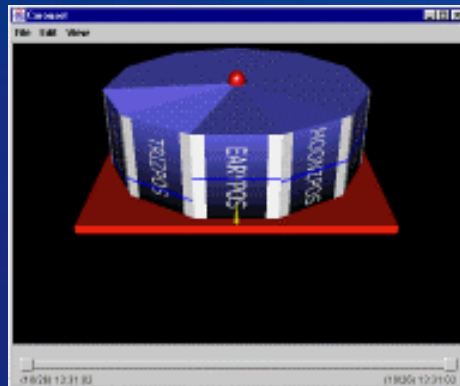
Constellation Console

- ✎ **Executive Summary always available**
- ✎ **All panes are resizable**
- ✎ **Tile, grid, or iconify any window**

CVS
Zoom User Interface (ZUI)
Screen Shots

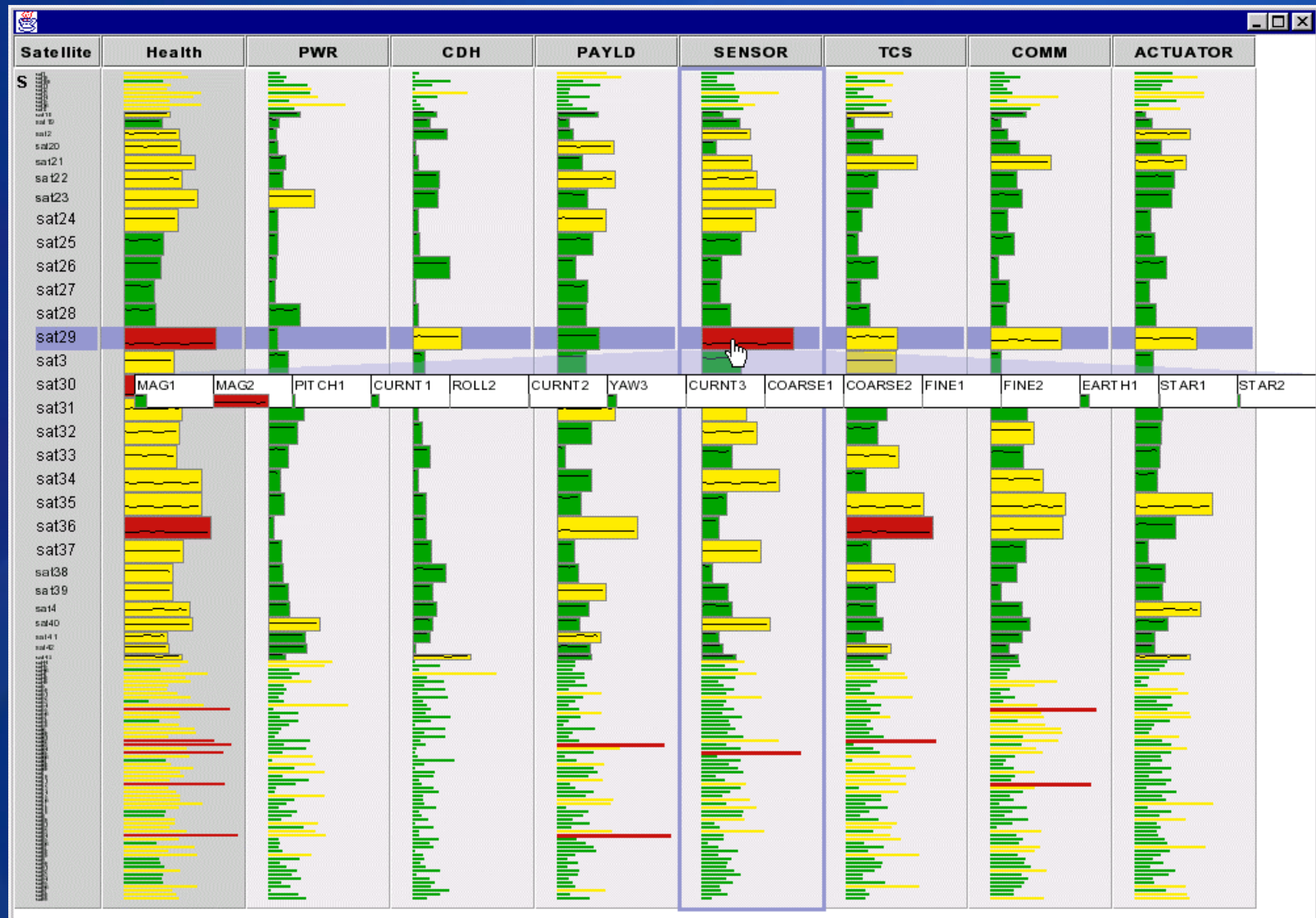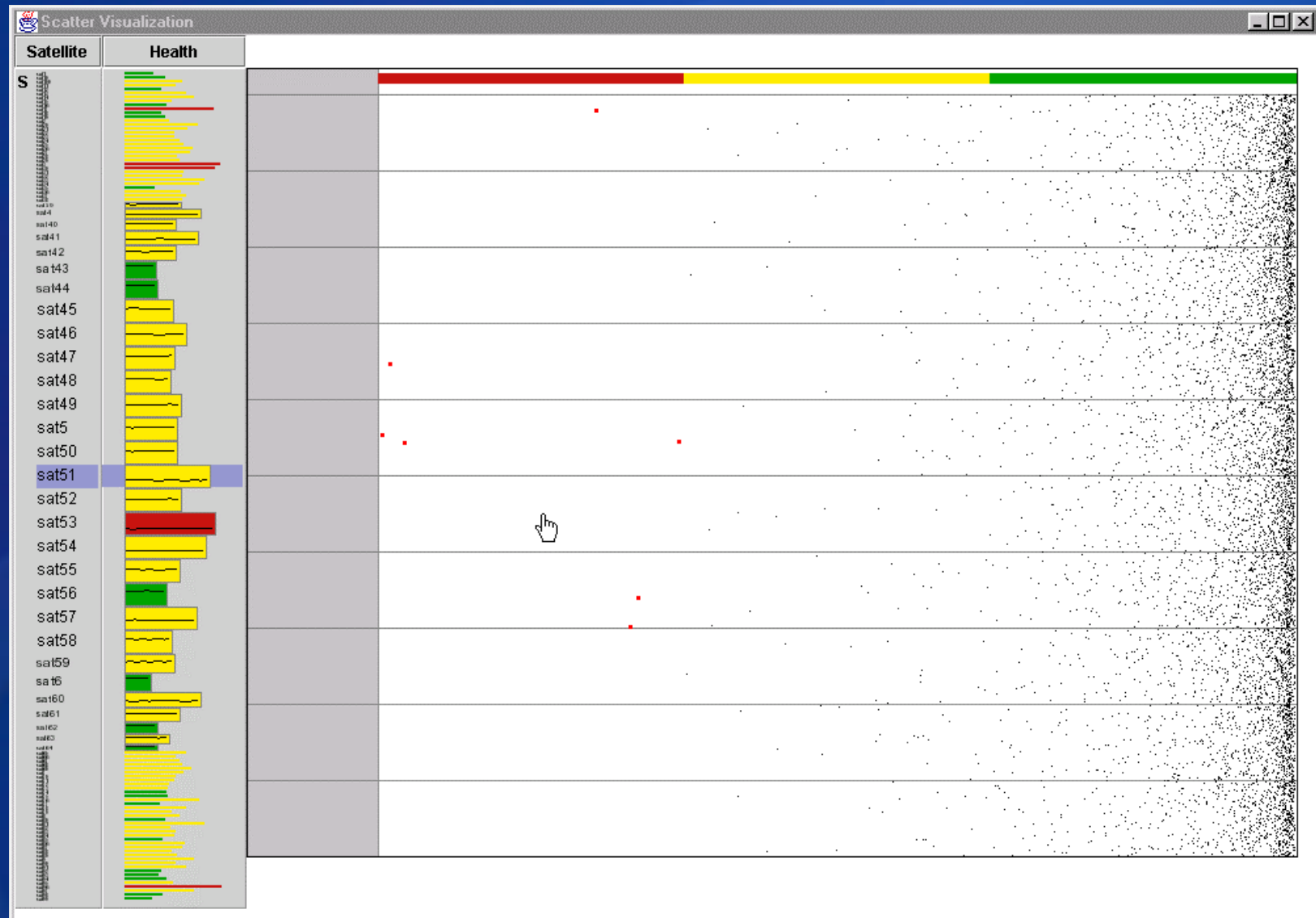# Fisheye View

Code 588/University Collaboration Workshop

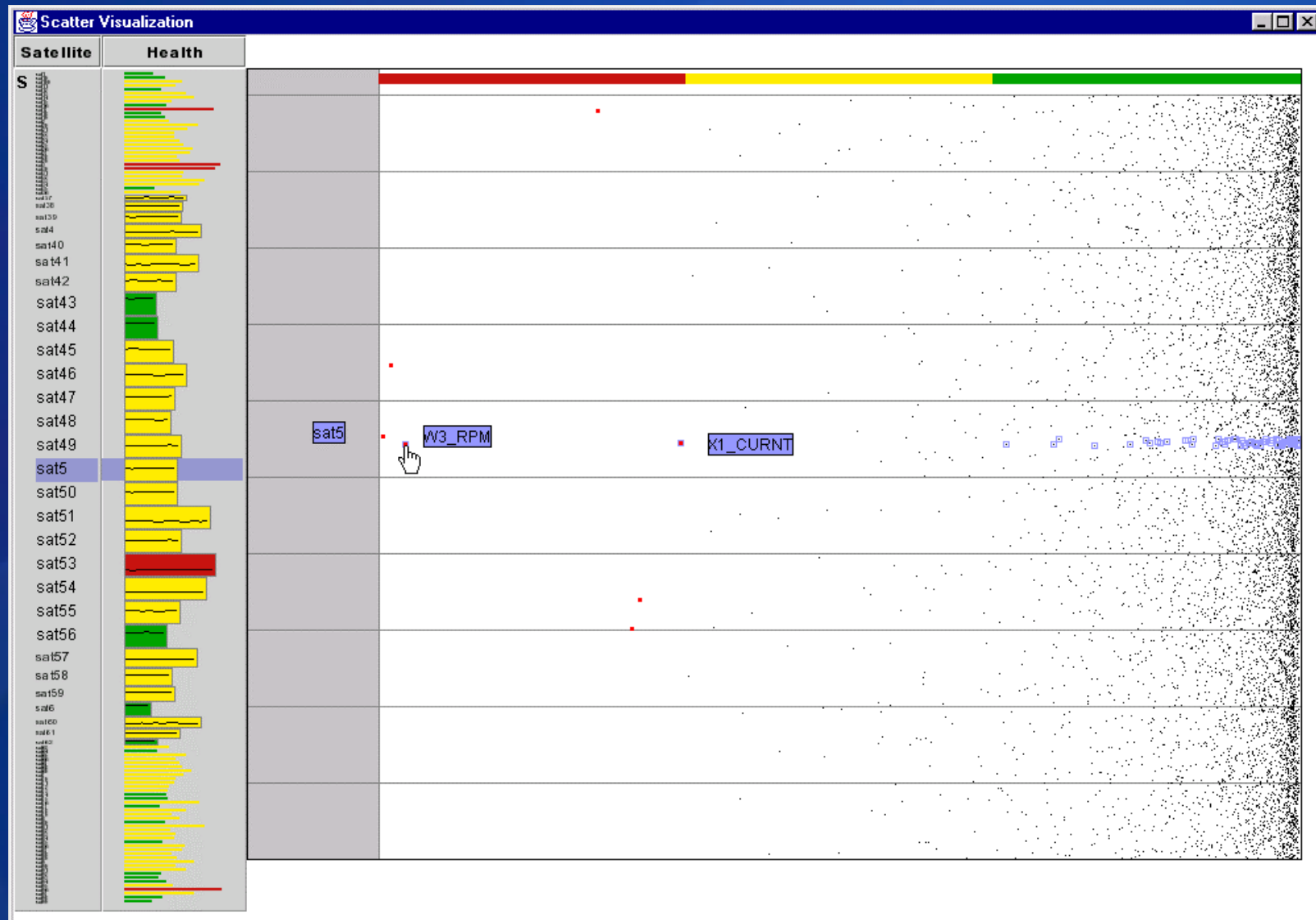# Fisheye View (2)

Scatter View
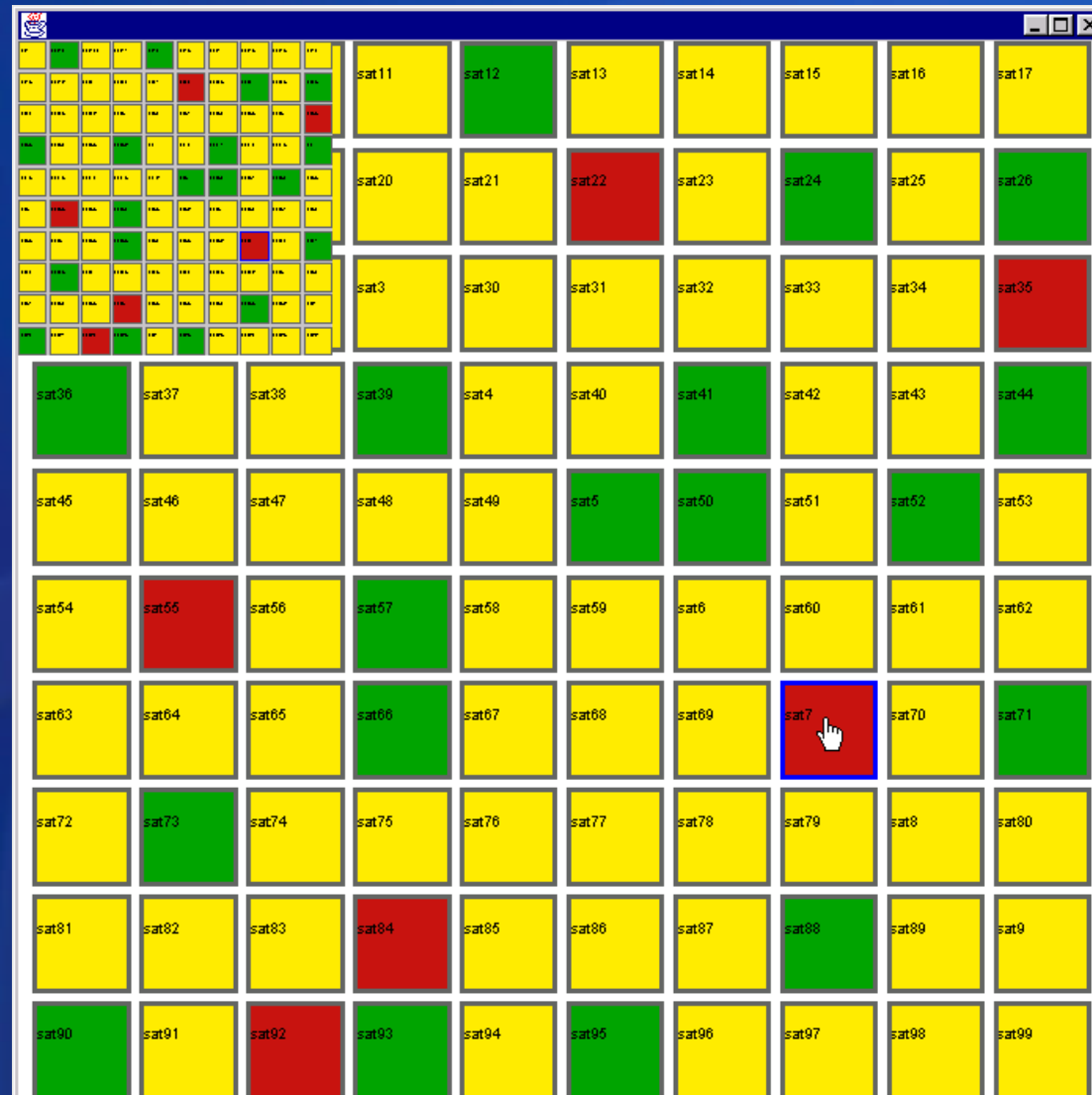
Code 588/University Collaboration Workshop

Scatter View (2)

Zoom View

Code 588/University Collaboration Workshop

Zoom View (2)
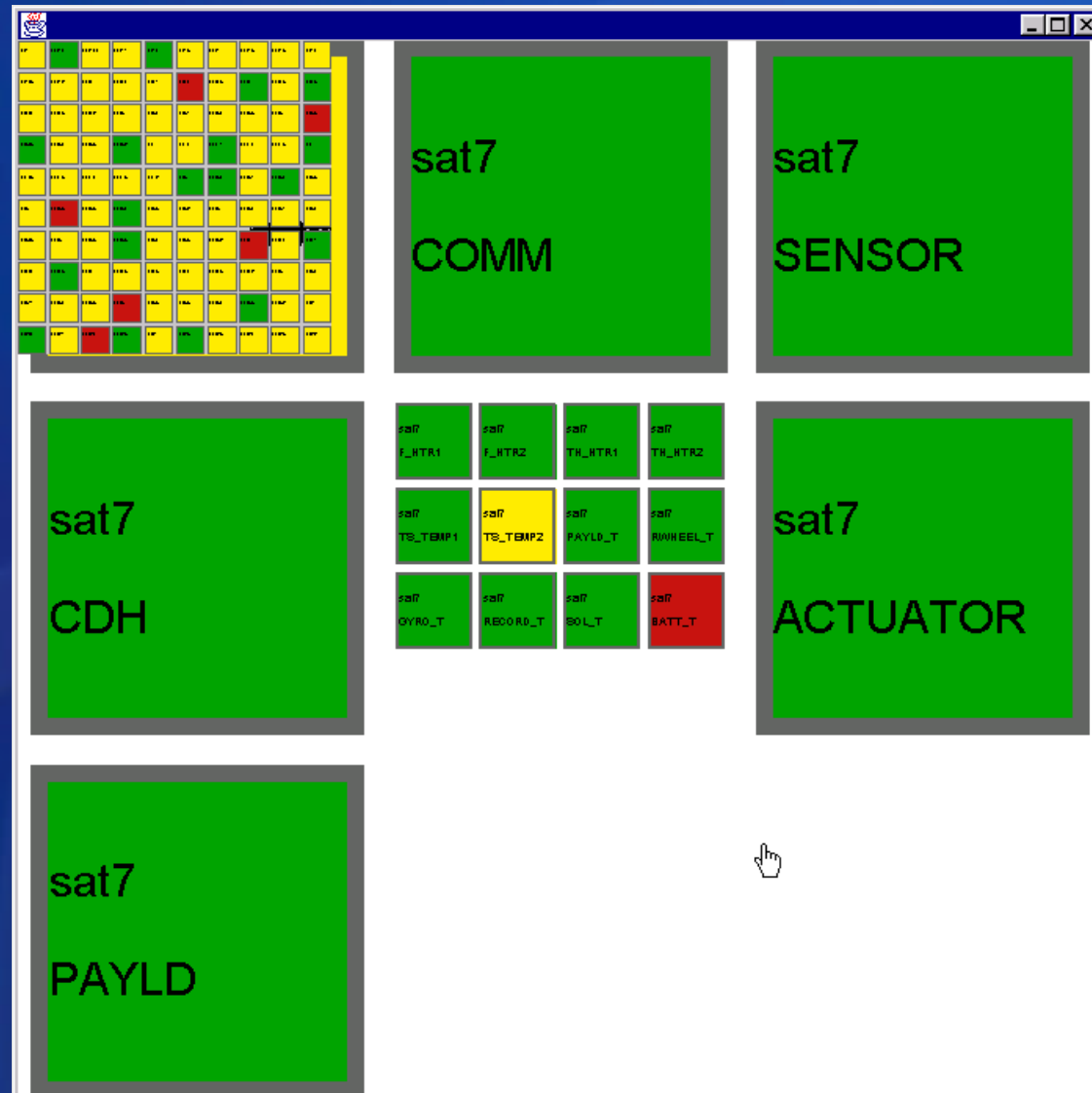
Visual Observation Layout Tool (VOLT)

VOLT - Project Overview

- **Goal**
    - **Provide a visual tool set for planning coordinated observations across multiple missions**
- **Features**
    - **Visual display of observatory schedulability data**
    - **Automated interfaces with mission planning facilities**
    - **Target selection/Constraint specification**
    - **Solution coordination for multiple missions**
    - **Expert constraint suggestions**
    - **Proposal ingest**

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VOLT - Project Overview

- Technical approach: Java-based client/server application
    - Gateway **Server**
        - Interfaces with target observatory planning facilities
        - Presents a single interface to the client
            - **Mediators** handle the detail for each supported **mission**
            - **Adaptors** handle the detail for each supported **interface**
    - **Client** utilizes a Model View Controller (MVC) pattern
        - **View** is the user interface that receives input from the user and presents scheduling related information on a display screen
        - **Models** represent the data, system state and how that information is to be presented
            - **Data Model** – provides data to view and maintains state of system
            - **Presentation Model** – specifies the presentation of the data
        - **Controller** –determines high levels actions based on user input

VOLT - Technologies

- **Technologies**
    - **Object Oriented Design and Analysis**
    - **Java/Java 2D**
    - **XML/HTML**
    - **Remote Method Invocation (RMI)**
        - **Java-based object communication mechanism**
        - **Primarily used for client/server communications**

Observation Setup Display
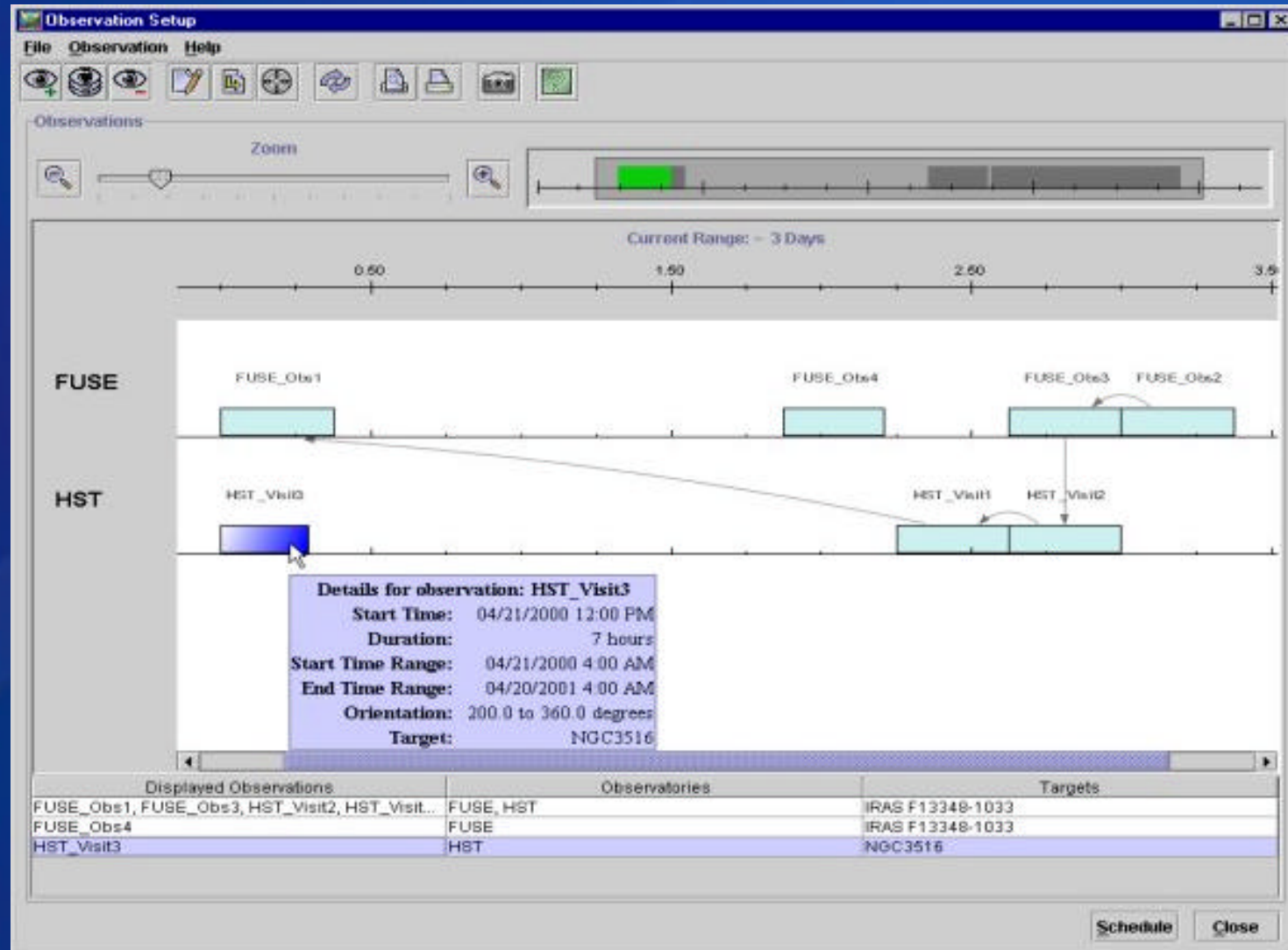
Schedulability Display
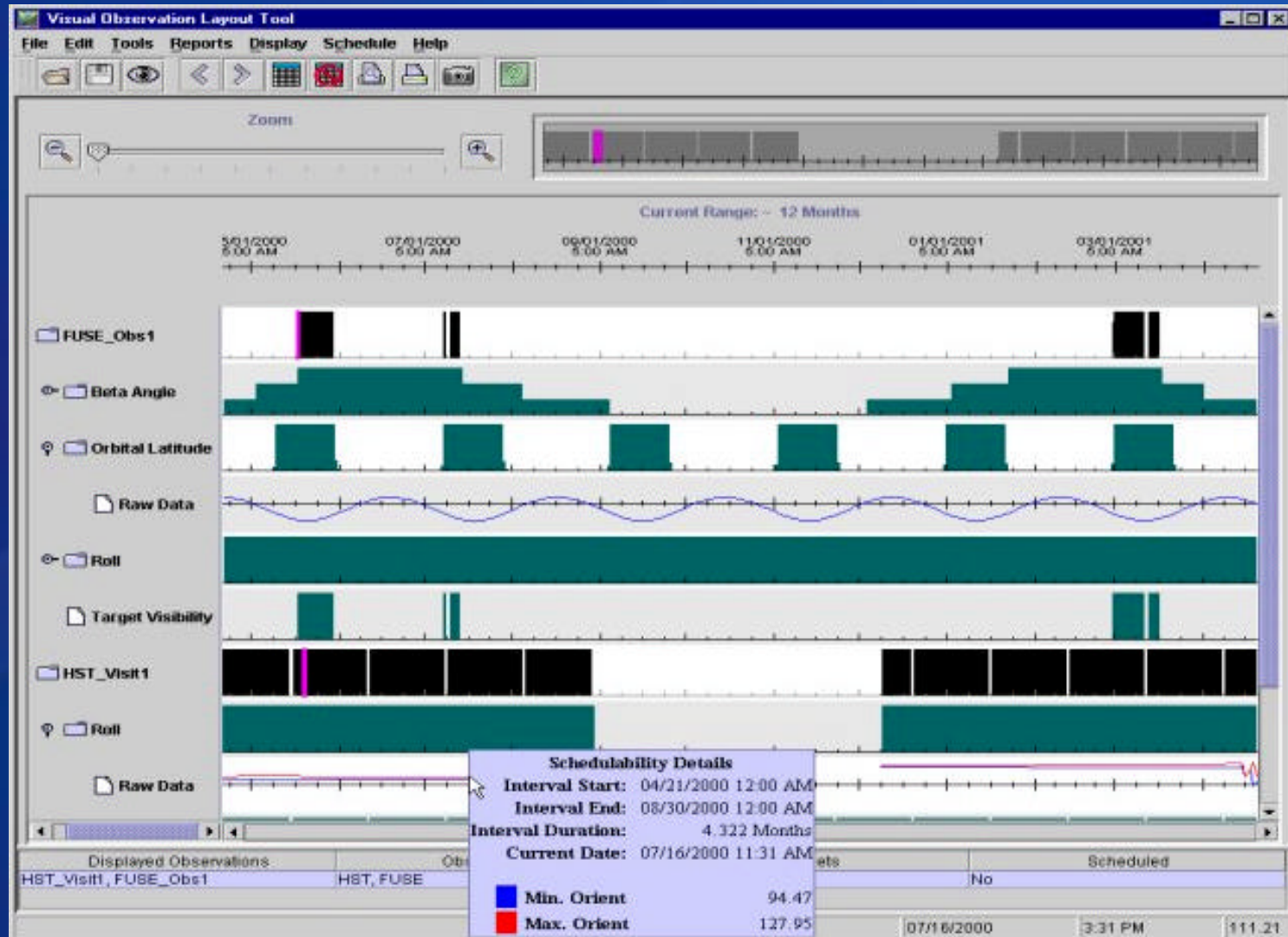
VOLT - Milestones / Schedule

- **Phase 1 - April 2000**
  - **Visual representation of merged observations**
- **Phase 2 - Aug 2000**
  - **Facility interfaces/Coordinate schedulability**
- **Phase 3 - Nov 2000**
  - **Constraint modification suggestions**
- **Phase 4 - March 2001**
  - **Extensibility (mission, proposal, constraint)**
- **Phase 5 – May 2001**
  - **User coordination, Schedule integration**
- **Phase 6 – July 2001**
  - **Ground-based observatories, Role types**
- **Phase 7 – Sept 2001**
  - **Accommodation of Earth Science missions**

VOLT - Research Opportunities

- **Techniques for conflict identification and resolution among multiple observatory schedules**

- **Adaptability to Earth Science domain**
  - **Current and near term efforts focused on Space Science domain**

Goal-Oriented Commanding (GOC)

GOC – Project Overview

- **Permits the direct tasking of an instrument, spacecraft or constellation using general scientific or engineering goals**
    - **Removes need to understand system artifacts & nuances of underlying system**
    - **Automates the step-by-step process of coordinating goals, constraints, and environmental conditions**
    - **Translates goals into command sequences with minimal intervention by operations personnel**
- **Applicable to a constellation environment**
    - **Based on a hierarchical, modular, and scaleable architecture**
    - **Allows onboard planning and resource management**
    - **Supports autonomous collaboration**

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Current Satellite Tasking Process
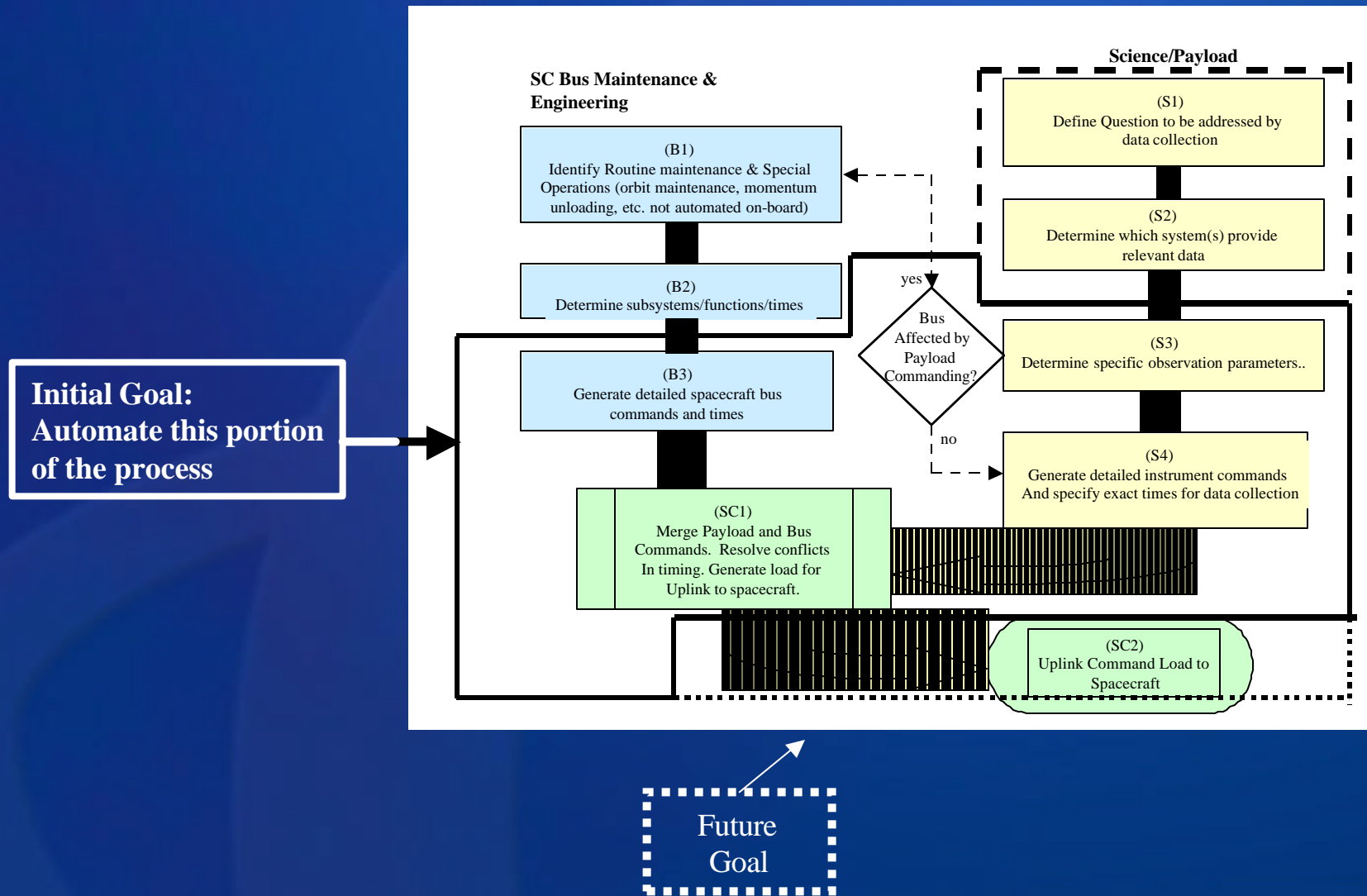
GOC Phase 2 Architecture

Scientist User Interface (Science Goals)

Domain Model Generator

Mission User Interface

Goal Interpretation Engine (GoalIE)

Domain Model

Resource Requests

Scheduling Engine (ASPEN)

Command Sequences

Uplink to S/C

Mission Inputs

Domain Specific Translator (DST)

Resource Availability

Command Load Generator

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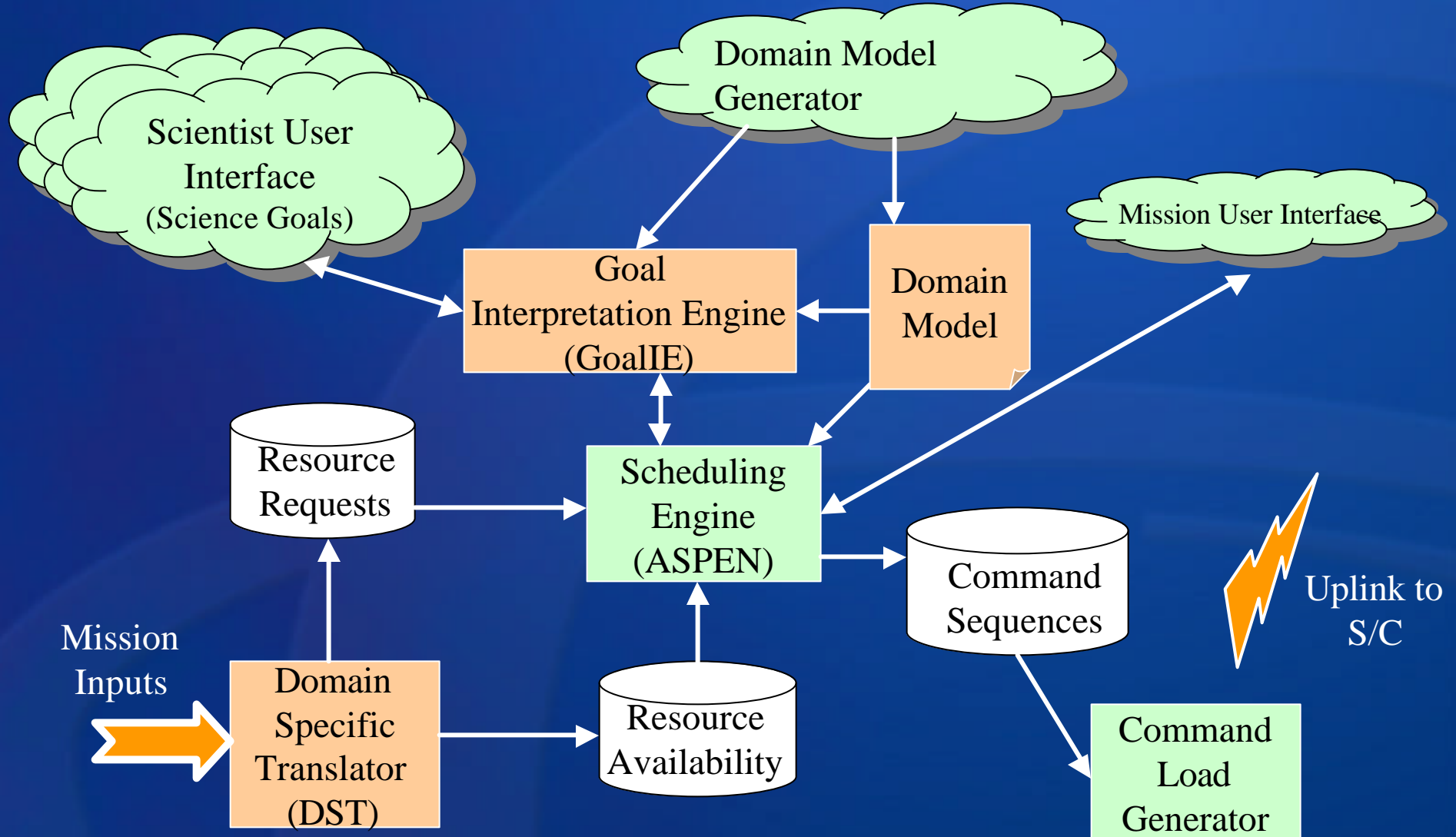
GOC Phase 3 Constellation Concept
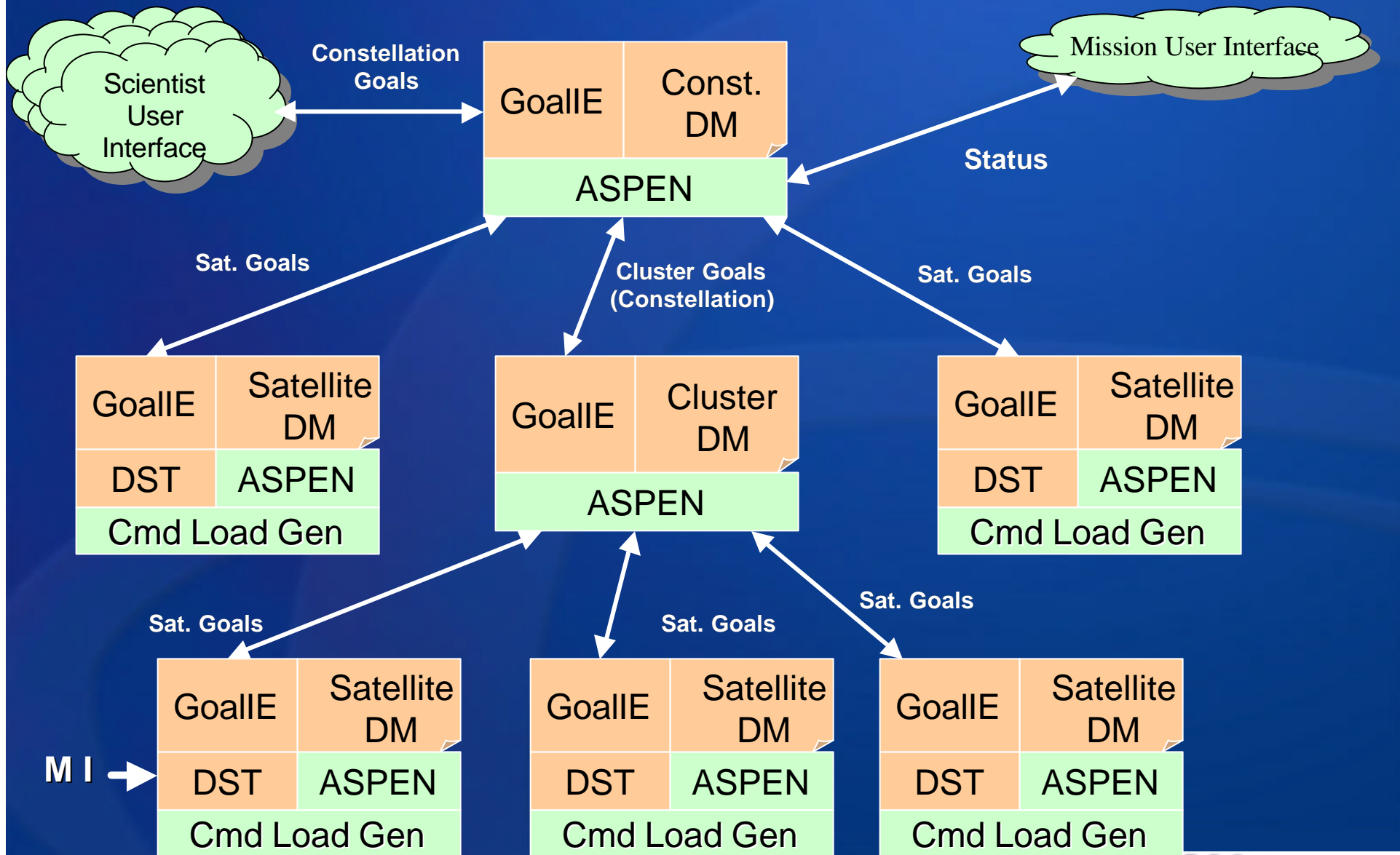
GOC - Milestones / Schedule

- **Phase 1 (FY01)** - **Demonstrate use of ASPEN (Instrument)**
  - **Partner with JPL (ASPEN) and EOSDIS (Terra SSR tool)**
  - **Requirements development and analysis**
  - **Concept of Operations**
- **Phase 2 (FY02)** - **Single Spacecraft Command Generation (Spacecraft)**
  - **Elementary goal oriented commanding**
- **Phase 3 (tbd)** - **Multiple Spacecraft Command Generation (Constellation)**
  - **Goal oriented commanding fully supported**
  - **Demonstrate scalability and hierarchical architecture**
- **Phase 4 (tbd)** - **Autonomous Collaboration**
  - **Onboard resource management and spacecraft collaboration**

GOC - Research Opportunities

- **Methods for users to express goals to system in an unstructured (human-like) way**
  - **Potential use of Natural Language**
- **Methods for identifying conflicts among goals and potential resolutions**
  - **Trade science priorities against operations constraints**
- **Methods for coordinating accomplishment of goals across multiple-spacecraft missions (e.g., constellations)**
- **Potential application of agent technologies**
  - **Ground and space-based**

Advanced Spacecraft Trend Analysis Toolkit (ASTAT)

ASTAT - Project Overview

- **Goal**
  - **Enable operations team to perform automated trending for single- and multi-spacecraft missions**
- **Benefits**
  - **Automated and interactive trend product generation**
  - **Direct interface to user analysis tools, e.g., MATLAB, EXCEL**
  - **Expert system shell for automated fault detection**
  - **Time- and event-driven trending**
  - **Cross-spacecraft comparisons**
  - **Internet- and Web-based access**

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ASTAT - Project Overview

- **Java-Based Client/Server Application**
  - **Server**
    - Retrieves telemetry data and definitions from data archive and project database
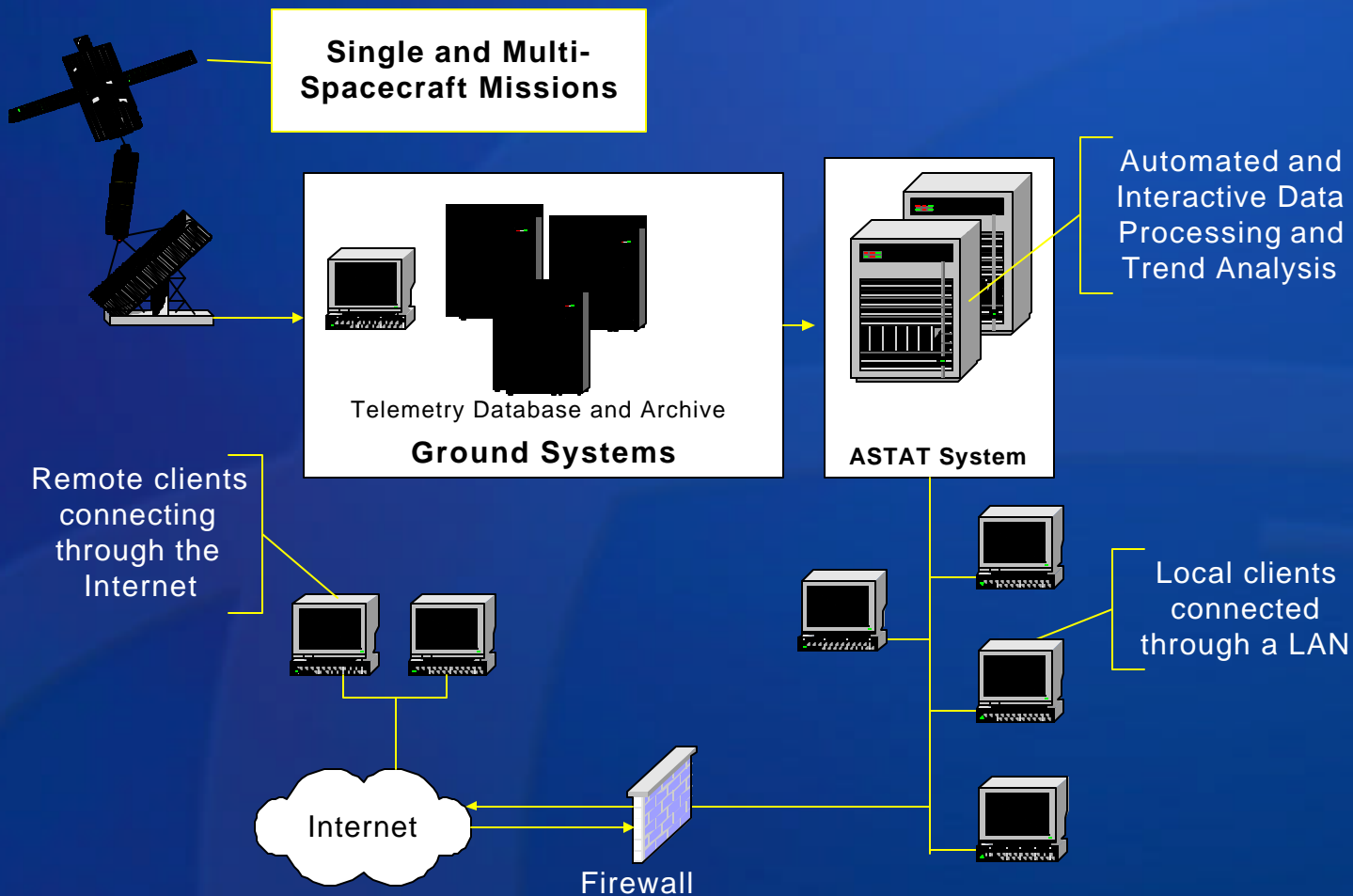   - Executes automated task list to generate trend products based on time and/or event triggers and on user-defined processing templates
    - Creates trouble reports when user-defined alarms are tripped, e.g., limit violations, time-to-limit thresholds exceeded, etc.
  - **Client**
    - Provides GUI for creating/viewing trend products and for documenting anomaly reports
    - Web-deployed PC client for standard use
    - Browser-based thin client for "on the road" access
    - Enables users to escalate trouble reports to anomaly reports for storage and future use

Operational Environment

Single and Multi-Spacecraft Missions

Telemetry Database and Archive

Ground Systems

ASTAT System

Automated and Interactive Data Processing and Trend Analysis

Remote clients connecting through the Internet

Local clients connected through a LAN

Internet

Firewall

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Home Screen

View Reports Screen

Trend Report Screen

ASTAT – Milestones / Schedule

- **Phase 1 (Sept 2001)**
  - **Infrastructure and Core Functionality**
    - Telemetry data import via sequential print file
    - GUIs for creating, viewing, upgrading trend reports
    - Cross-spacecraft trending
    - Time- and event-based trend product generation
    - Fault detection based on limit violations
- **Phase 2 (Sept 2002)**
  - **Upgrades and Enhancements**
    - Telemetry import via data archive and project database
    - Computation and trending of derived mnemonics
    - Fault detection using stored telemetry signatures
    - State-space representation of spacecraft health/status
    - Expert system shell for fault detection
    - Fault prediction based on telemetry limits and curve fits

Applied Agent Research and Multi-Agent Systems (MAS)

Project Overview

- **Goal:**
  - **Conduct advanced research in agent technologies and investigate how they can be applied to autonomous observatory (spacecraft and instrument) operations and information management**

- **Research primarily organized into 4 areas:**
  - **Multi-Agent System for SOHO**
    - **Ground-based orbit and attitude determination**
    - **Virtual distributed (GSFC & JPL) community of agents mapped to spacecraft subsystems**
  - **On-board autonomous instrument operations**
    - **On-board virtual principle investigator capable of adapting over time to achieve science goals, maintain health& safety of instrument, etc.**
    - **Model-based reasoning, aware of context in which it is operating**
  - **Ontology Negotiation**
  - **Intelligent Information Management**

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Multi-Agent System for SOHO

SOHO

Application

Applied Research

SOHO Subsystem₁ ↔ Surrogate Analyst(s) Subsystem₁

Observation   Dialog

Control Center Personnel

- Modeling
- Communication
- Reasoning
- Agent Community Dynamics
- Intelligent Information Management
- Adaptation/Learning

Required for SOHO application development

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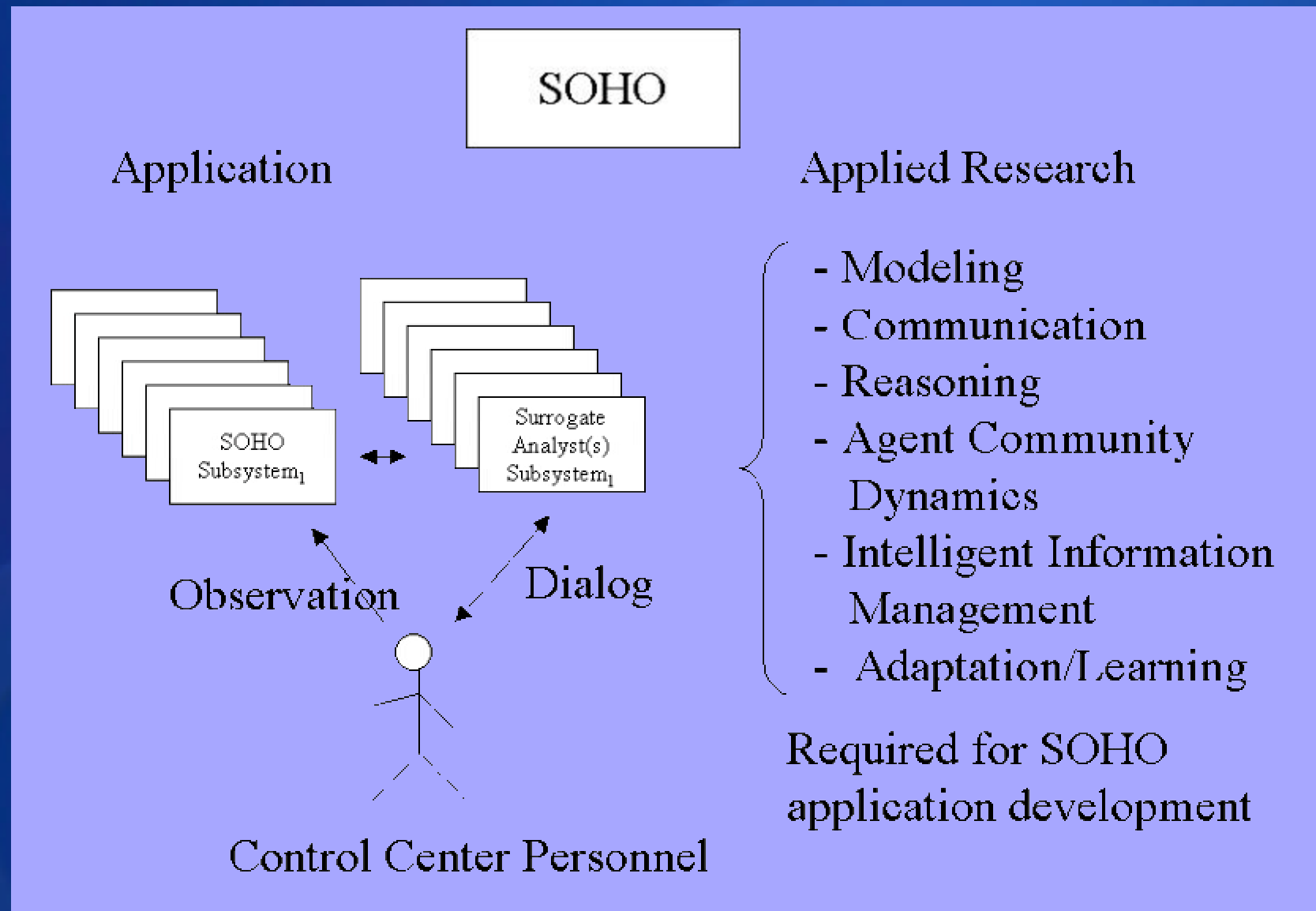
Multi-Agent System for SOHO

Supervisor agent – manages communications /interactions among agents in community

JPL Agent Community

JPL User Interface Agent

External Process (e.g. satellite bus)

Broker

Orbit Agent Community

External Process (e.g. FreeFlyer)

Attitude Agent Community

User Interface Agent
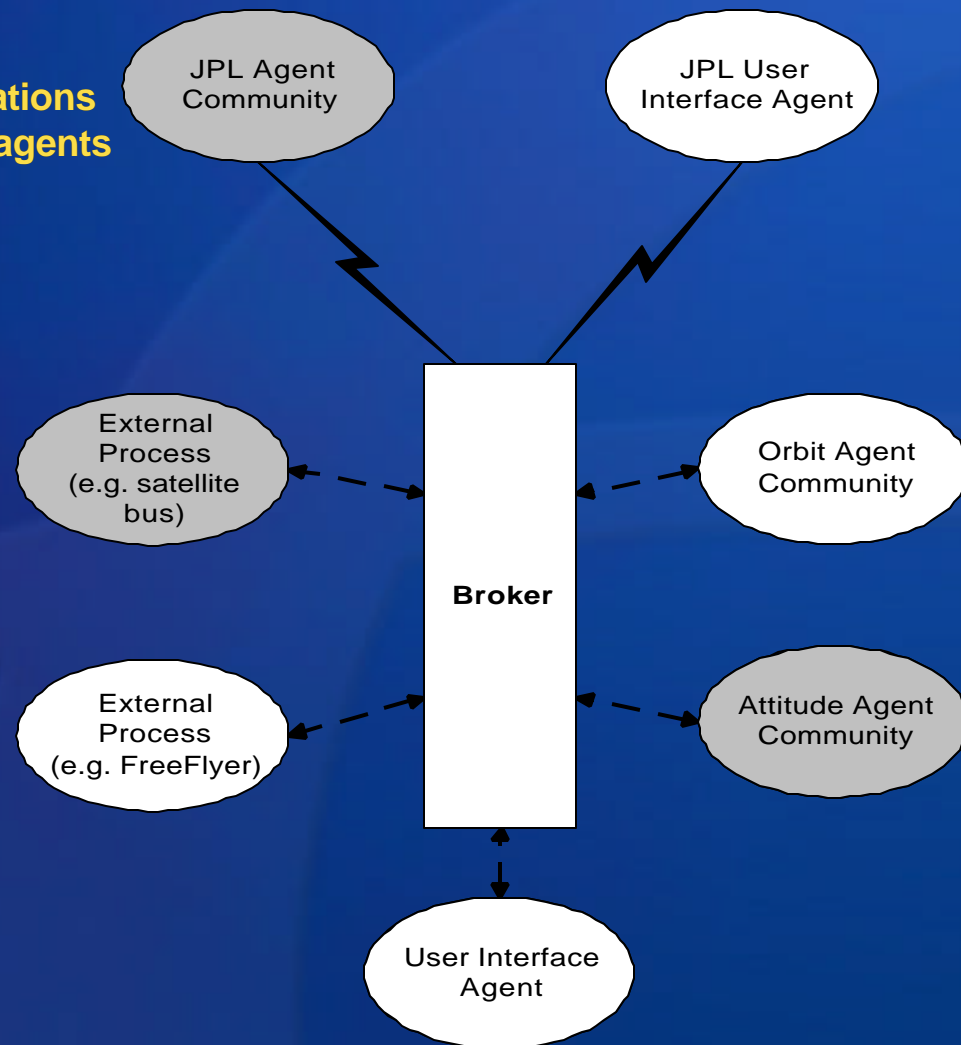
Attitude agent – ground-based automated attitude (pointing) management

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Automated Instrument Operations

Spacecraft

Other spacecraft subsystems

Instrument

I

Data
- -
I
- -

Surrogate PI

Computer-based model
of the instrument and
its behavior –
codification of
PI's understanding

Data
- -
I
- -

PI's understanding
of the instrument and
its behaviors

Ground-based PI

PI-Instrument dialog
for science agenda
planning and instrument
monitoring

There are two major components
of this PI-Instrument interaction:
- ground-instrument dialog
- intelligent instrument-management
   process

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Ontology Negotiation

- Process of negotiation and communication among **heterogeneous** community of agents
  - Agents use various techniques to understand each others' domains – to come to terms with each other's view of the world (their **ontology**)
- **Negotiation** allows different types of agents to interact and communicate in a meaningful way
- Researching advanced concepts in approaching agent negotiation and how it can be applied
  - Currently prototyping agent communication between NASA and NOAA spacecraft data bases (heterogeneous agents) for query searching
    - Schema is the ontology, basis of negotiation is the common nature of the data
  - In future will expand to broader queries

Ontology Negotiation

- **Ontology negotiation combines aspects of agent modeling and ontology sharing.**

- **Rather than simply adding the other agent's ontology to its own, each determines how to understand the other's ontology within the conceptual framework that it already possesses**

Modeling Other

Sharing Ontologies

Negotiating Ontologies
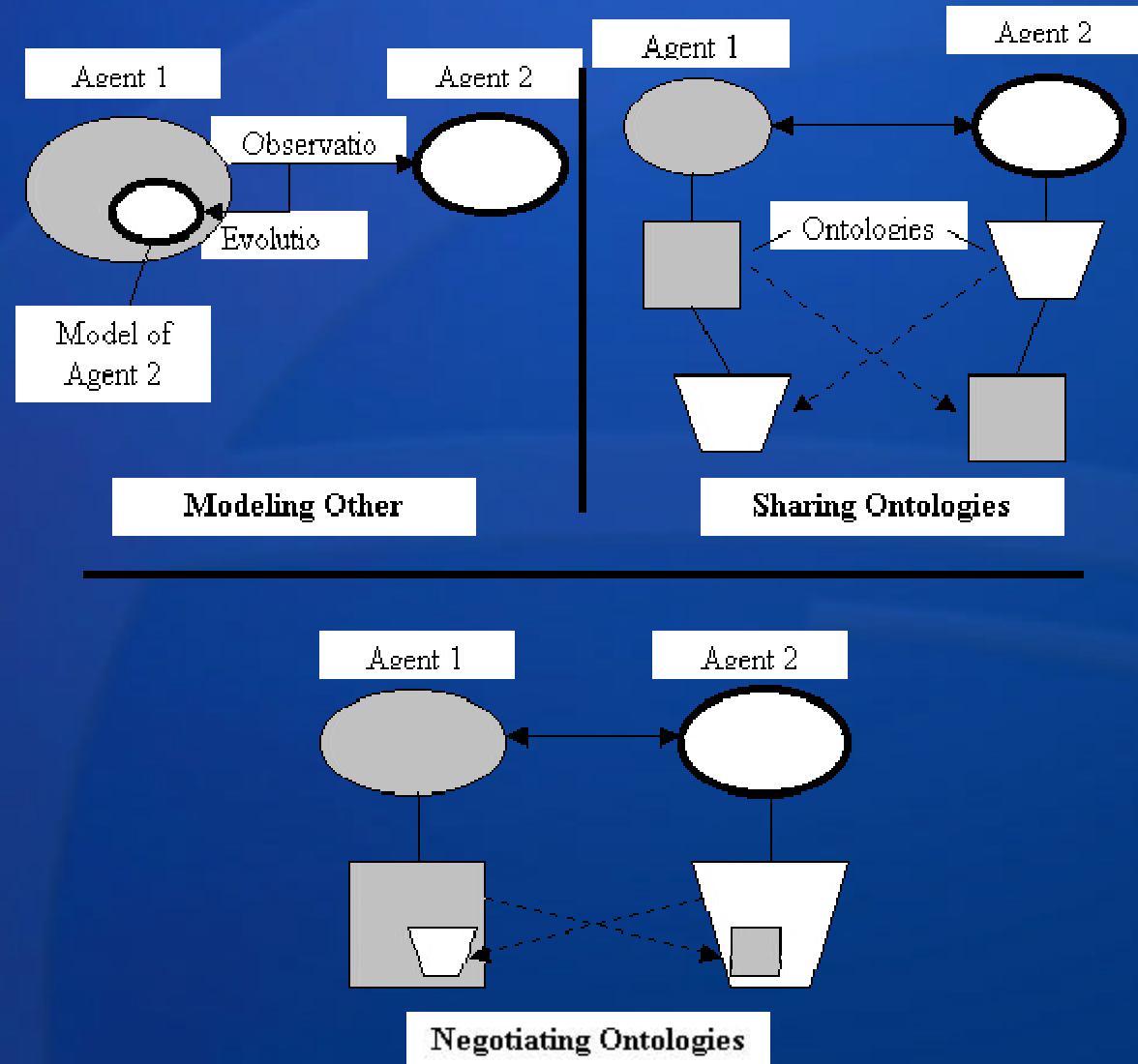
Intelligent Information Management

- Investigating agent-based data mining techniques and applications
  - **Task 1** – Mining information on new and emerging agent technologies available on the Web
    - Using COTS-tool "My Gold Digger"
    - May lead to more generalized mining approaches
  - **Task 2** – Mining heterogeneous data sources for user-selected topics of interest
    - Allows users to search a collection of data sources (e.g., data bases, documents, presentations, Web sites) for specific information
    - System returns summary of where the requested information can be found
    - Using "Autonomy" data mining tool
    - Collaborating with JPL – providing data sources and assistance in analyzing mining tool

Technologies

- ? **Java**

- ? **Agent XML (AXML)**

- ? **Knowledge Query Management Language (KQML)**
    - ? **Agent communication language**

- ? **"Agent Builder Pro"**
    - ? **Agent builder tool being used for SOHO**

- ? **"My Gold Digger" and "Autonomy"**
    - ? **Agent-based data mining tools**

Milestones / Schedules

- **Multi-Agent System for SOHO**
    - **March '01** – Initial demo: orbit determination agent
    - **Sept '01** – Demo of attitude control and JPL's supervisor agents
- **Ontology Negotiation**
    - **Nov '00** – NASA/NOAA data base testbed (COMPLETE)
    - **Sept '01** – Enhanced testbed with broader queries and larger portions of data bases
- **Intelligent Information Management**
    - **April '01** – Prototype demo of My Gold Digger"
        - Searching Web for new/emerging technology information
- **On-Board Autonomous Instrument Operations**
    - Schedule being worked

Research Opportunities

- **Agent adaptability & learning techniques**
  - **Ability to adapt to changing environments**
- **Agent communication dynamics**
  - **Mechanisms for agents joining/leaving a community, forming alliances, etc.**
- **Person-to-agent dialog**
  - **Possible application of Natural Language**
- **Innovative ways to approach ontology negotiation**
- **Innovative ways to represent knowledge and information within agents**
  - **Provides ability for agent to be used in multiple situations, e.g., across different kinds of instruments**

Questions???

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